

Ecological and Radiation Assessment of the State of Drilling Waste and their Disposal Products on the Example of the Khanty-Mansiysk Autonomous Okrug – Yugra

Valentina M. Okmyanskaya^{1*}, Olga V. Bogdanova¹

¹ Federal State Budget Educational Institution of Higher Education, Industrial University of Tyumen, Volodarskogo 38, 652000 Tyumen, Russia

* Corresponding author's e-mail: okmjanskajvm@tyuiu.ru

ABSTRACT

The development of the infrastructure of the oil and gas complex is one of the most significant factors of negative impact on the environment. The most efficient way to drill wells is cluster drilling, which currently accounts for 95% of all operations carried out in fields. In the process of oil and oil products production, toxic drilling waste is generated at the well pad, which is then placed in sludge pits (sludge storage). The aim of the study was to select the methods for drilling waste utilization based on the results of environmental radiation analysis. Within the framework of the study, the following tasks were solved: radiation monitoring of drilling waste was carried out at the “Progress-2000” spectrometric complex; analyzed the physical and chemical composition of drill cuttings; a comparative analysis of the samples under study was carried out in accordance with the normative indicators; methods of utilization of drilling waste are proposed.

Keywords: ecological safety, environment, oil production, license area, drill cuttings, environmental and radiation assessment, specific effective activity.

INTRODUCTION

The issues of ecological safety and environmental protection are becoming more and more urgent under the conditions of man-made pressure on natural ecosystems. The current regulatory and legal documents in the field of environmental safety, state programs, increasing the efficiency of monitoring of ecological systems and ensuring the quality of the environment, increasing efficiency, strategic planning documents in the field of regulating the quality of the environment determine the problem under consideration [Mitko, 2019].

During the extraction of hydrocarbons, environmental pollution occurs both at well pads and on the territory of sludge storage facilities, where drilling waste in the form of drill cuttings needs further disposal and processing. When interacting with the natural environment, the drilling fluid can have a negative impact on

the natural balance of biocenoses with unpredictable behavior of these complexes in the future. To prevent this negative impact, drill cuttings require neutralization and environmentally friendly disposal [Mironov et al., 2014, Meshcheryakov et al., 2017]. The following main directions of utilization of drilling waste are known: physical, chemical, physicochemical, thermal and biological [Yagafarova et al., 2018]. The search for a safe way of handling drilling waste at the industrial sites of oil producing companies is currently an urgent issue [Zha et al., 2017].

Khanty-Mansiysk Autonomous Okrug – Yugra has a huge natural resource potential, the main oil and gas region of Russia and one of the oil-producing regions of the world. Natural capital is one of the main components of the development of the territory. However, the resource specificity of the territory, geographic and climatic features, as well as the development of the industrial sector, determine the main environmental problems

of the Autonomous Okrug: pollution of atmospheric air, water bodies and lands, problems of waste disposal, transformation of the habitat of flora and fauna.

Within the framework of this study, at the Teplovskoye and Kudrinskoye fields, an area in the Nefteyugansk region of the Khanty-Mansiysk Autonomous Okrug – Yugra, a technological method was proposed for processing drill cuttings and adding them to building materials for further use. In this regard, it became necessary to use various methods of using the materials under study.

MATERIAL AND METHODS

The following equipment was used to conduct radiation and environmental monitoring of the study area: DKS-96 dosimeter-radiometer with a BDVG-96 detection unit; dosimeter of gamma radiation DKG-07D “Drozd”; device for monitoring air parameters MES-200A; Garmin GPSMAP 62 stc navigator; spectrometric installation MKS-01A “MULTIRAD”.

During the execution of the work, measurements of the rate of the ambient equivalent dose of gamma radiation were performed. The measurements also involved the meteorological parameters – temperature, air humidity, atmospheric pressure and wind speed, and were carried out using the device for monitoring the parameters of the air environment – MES-200A.

Along the route survey of the site, a by-pass of the territory was carried out in order to identify the possible sources of pollution of soils, grounds, atmospheric air, as well as actual visual signs of pollution of the territory.

Pedestrian gamma survey was carried out with a DKS-6 search dosimeter-radiometer with a BDVG-96 detection unit, at a distance of 1 m and 10 cm above the ground and on the surface of the equipment, at least 5 times at each point with the calculation of the average result in order to identify and localize the possible radiation anomalies throughout the study area. Moreover, to obtain the results of AEDR, a dosimeter of gamma radiation DKG-07D “Drozd” was used. The recording of the intensity of gamma radiation in the act of radiation research was carried out in $\mu\text{Sv/h}$.

To assess the influence of heavy metals that make up the drill cuttings, the chemical composition was studied by atomic emission spectroscopy.

The studies of the radiation safety of drill cuttings were carried out using the MKS-01A “MULTIRAD” spectrometric unit of the “Progress” spectrometric complex [Interstate standard GOST 30108-94].

RESULTS

Khanty-Mansiysk Autonomous Okrug-Yugra is an oil and gas producing region, 70% of the territory is in the stage of active development, 85 companies owning 589 long-term licenses for the right to use subsoil for the purpose of exploration and production of hydrocarbons (Fig. 1), the length pipeline networks 109.8 thousand km (intra-, interfield, trunk) [Order dated 06.28.2019 № 103-p]. There are 475 territories of traditional nature management of regional significance registered within the borders of the Autonomous Okrug.

Ecological and radiation assessment of drilling waste was carried out on the territory of the Teplovsky and Kudrinsky license areas located in the Nefteyugansk region of the Khanty-Mansiysk Autonomous Okrug – Yugra.

The Nefteyugansk region is located in the central part of the Autonomous Okrug, is one of the leaders (after the Surgut, Nizhnevar-tovsk and Khanty-Mansiysk regions) in terms of reserves and production of hydrocarbons in the Khanty-Mansi Autonomous Okrug – Yugra (Fig. 2), the discovered deposits account for 47% of the total number of deposits, opened on the territory of the district.

Geographically, the territory of the Teplovsky license area is located in the southern part of the Sredneobskaya lowland, on the left bank of the Ob river, in its lower reaches of the Small Balyk river. The relief on the site is flat. The Teplovsky license area is 220.1 km².

The Kudrinsky license area is located in the central part of the Sredneobskaya lowland, in the middle reaches of the Small Balyk and Pytyakh rivers. The relief in the studied areas is represented, as a rule, by an undivided complex of terraces of flat-boggy river valleys. The area of the Kudrinsky license block is 53.29 km² [Bogdanova 2011].

A characteristic feature of the study area is a strong graininess and swampiness. Figure 3 shows a diagram of the boundaries of the considered license areas.

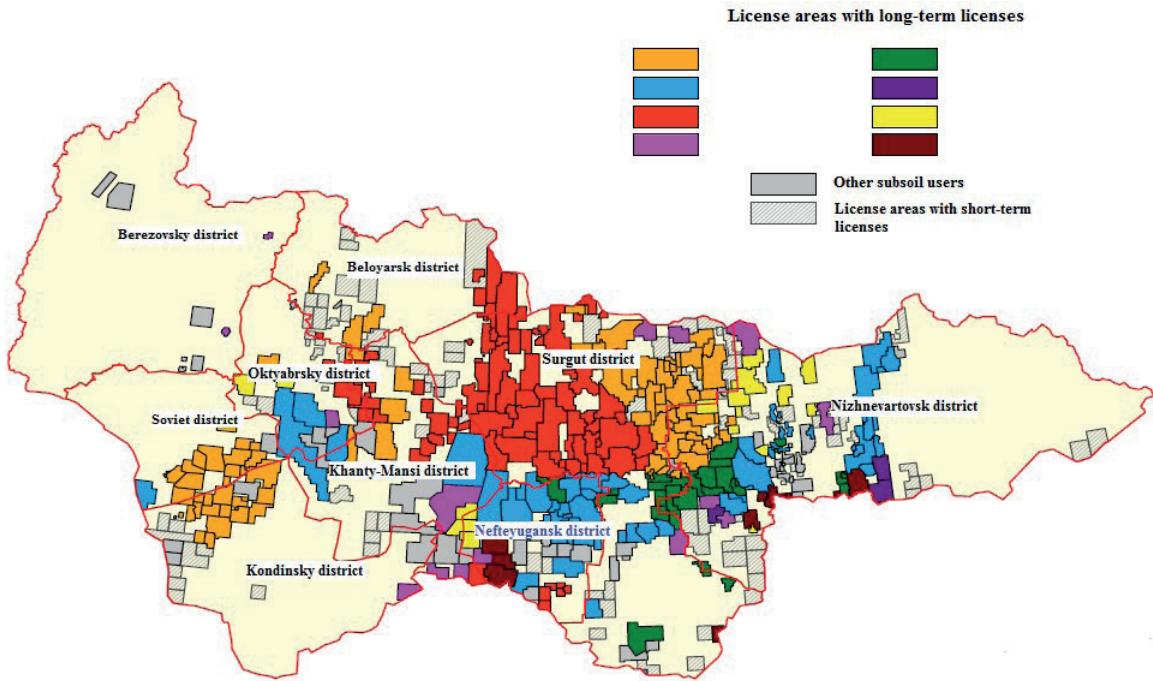


Figure 1. Map of license areas of KhMAO – Yugra

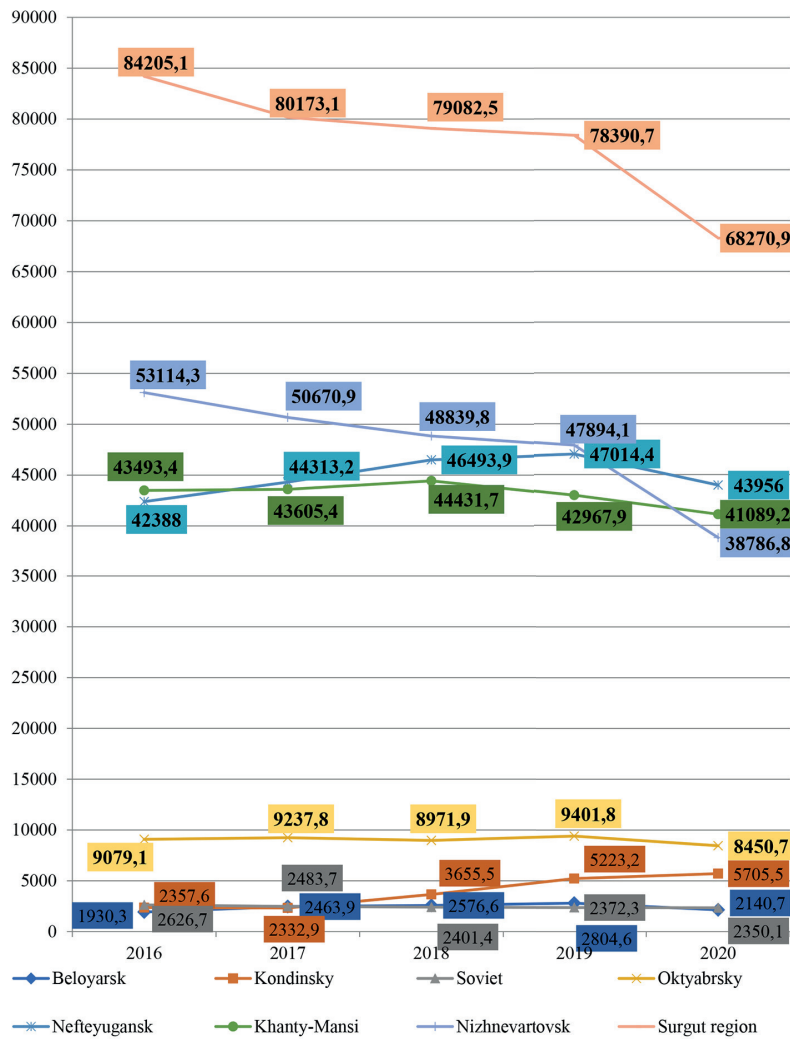


Figure 2. Oil production by administrative districts of the Autonomous Okrug, thousand tons

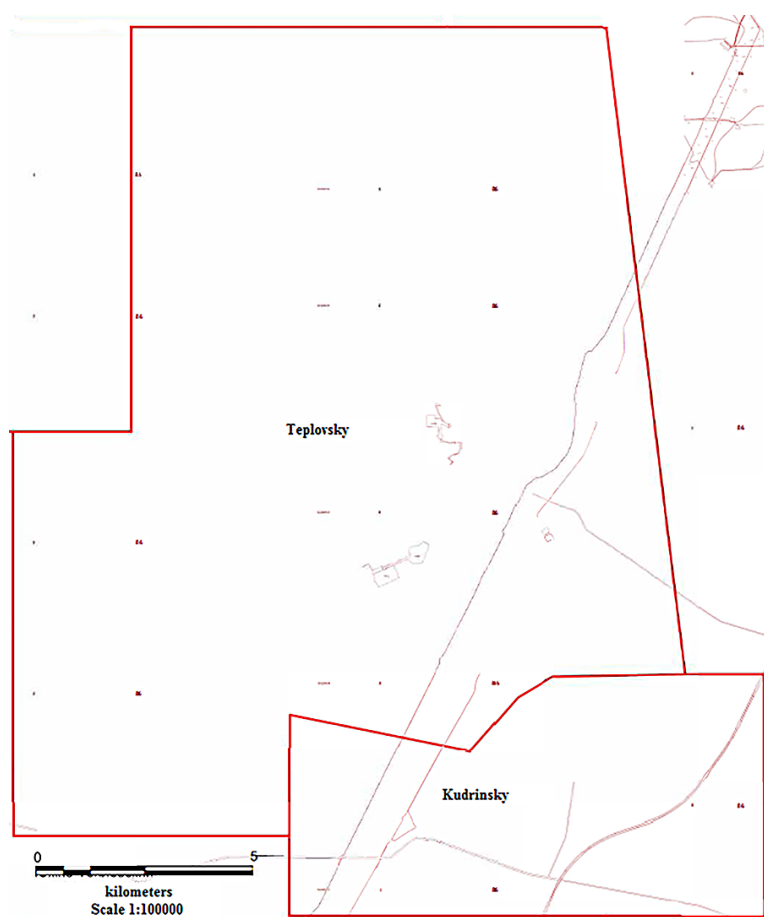


Figure 3. Scheme of the boundaries of the Teplovsky and Kudrinsky license areas

At these licensed areas, gamma radiation dosimetry was carried out at storage sites for tubing, pumps, oilfield equipment, fuel storage sites, workplaces, well pads and other industrial facilities.

The results of dosimetric gamma radiation are presented in Table 1. According to the results of observations, it was found that the concentration of all monitored indicators at industrial facilities does not exceed the standard values.

In order to minimize the negative impact on the environment, the following directions of disposal of drill cuttings were proposed: the use of drill cuttings as a mineral powder in an asphalt concrete mixture and the production of cement-based soil for road construction on the basis of drill cuttings.

As part of the study, laboratory studies of drill cuttings were carried out to determine the physicochemical parameters and the content of heavy

Table 1. Dosimetric control of gamma radiation of industrial facilities

License area name	Quantity	Result and measurement error, $\mu\text{Sv} / \text{h}$	Norms for the results of gamma survey, $\mu\text{Sv} / \text{h}$
Kudrinsky	KT-1	0.12 ± 0.04	0.6
	KT-2	0.14 ± 0.04	
	KT-3	< 0.10	
	KT-4	0.10 ± 0.04	
	KT-5	0.13 ± 0.04	
Teplovsky	KT-1	0.13 ± 0.04	0.6
	KT-2	0.10 ± 0.04	
	KT-3	0.10 ± 0.04	
	KT-4	< 0.10	
	KT-5	0.11 ± 0.04	

Table 2. Content of heavy metals in drill cuttings samples

Name	Heavy metal content, mg / kg			
	Cr	Pb	Cu	Mn
Drill cuttings № 1 (Kudrinsky license area)	1.3	1.8	1.4	106
Drill cuttings №. 2 (Teplovsky license area)	0.98	2.4	1.8	114

Table 3. Physical and chemical indicators of drill cuttings samples

Name	Determined characteristics				
	pH, quantity pH	Moisture content, %	Petroleum products, %	Sulfate ion, mg / kg	Chlorides, mg / kg
Drill cuttings № 1 (Kudrinsky license area)	11.67	32.58	0.96	306	94
Drill cuttings №. 2 (Teplovsky license area)	10.04	27.88	0.84	365	206

Table 4. Content of natural radionuclides in drill cuttings samples at Teplovsky and Kudrinsky license areas

Sample weight, g	Measurement results, Bq/kg						
	Quantity	²²⁶ Ra	Quantity	²³² Th	Quantity	⁴⁰ K	Specific effective activity
Kudrinsky license area							
500	21.2	18.4 ± 4.9	11.9	11.3 ± 2.3	370	357 ± 80	63.4 ± 6.5
500	16.6		10.7		349		
500	17.7		9.5		371		
500	21.1		11.5		333		
500	15.2		12.7		361		
Teplovsky license area							
500	12.9	13.0 ± 3.7	8.5	9.6 ± 2.4	360	369 ± 77	56.9 ± 8.2
500	12.3		9.3		388		
500	10.8		8.9		325		
500	15.7		11.9		401		
500	13.3		9.6		370		

metals. The content of heavy metals in drill cuttings samples is shown in Table 2.

Analysis of the results of laboratory studies has established that there is no excess of the standards for the content of heavy metals in mobile form.

In addition, water extracts were prepared from the samples of drill cuttings dried at 105°C to constant weight to determine the physicochemical parameters. The research results are shown in Table 3.

The results of studies of the content of natural radionuclides in drill cuttings samples at the fields and the parameters of the specific effective activity at the Teplovsky and Kudrinsky license areas are shown in Table 4 [Nazirov et al., 2012].

While analyzing the content of natural radionuclides in drill cuttings samples, the highest values were noted in relation to ⁴⁰K. The maximum concentration for this component was 369 Bq/kg

at the Teplovsky license area. The concentration of this component was slightly lower at the Kudrinsky license area and amounted to 357 Bq/kg.

The activity of ²³²Th and ²²⁶Ra, in contrast to ⁴⁰K, did not have significant indicators. The maximum concentration of ²³²Th in all investigated samples of drill cuttings did not exceed 12.7 Bq/kg with a minimum indicator of 8.5 Bq/kg. The ²²⁶Ra concentrations ranged from 10.8 to 21.2 Bq/kg.

During the period of the work, 10 soil samples were taken at two sampling points. At each sampling point, five soil pits were laid, where point samples were taken from a depth of 0.05–0.20 m (suprapermafrost layer). The mass of one sample is 1 kg. The soil samples were crushed and thoroughly mixed. The possibility of secondary contamination of the samples was excluded by cleaning the wall of the soil section with a plastic scraper before sampling.

In accordance with regulatory documents, the soil samples are taken within the identified radiation anomalies at points with a maximum dose rate in layers about 10 cm thick with measurement of the dose rate at the bottom of a hole with a plan size of at least 0.5 by 0.5 m after removing each layer [GOST 17.4.3.01-2017].

Effective specific activity of natural radionuclides in building materials (raw materials) mined at their deposits (crushed stone, gravel, sand, rubble and sawn stone, cement and brick raw materials, etc.) or being a by-product of production, in industrial waste used for manufacturing building materials (ash, slag, etc.), as well as in finished products, was calculated using the formula (1) [Sanitary rules and norms 2.6.1.2800-10].

$$A = A_{Ra} + 1.31A_{Th} + 0.085A_K \quad (1)$$

where: A_{Ra} and A_{Th} – specific activities Ra-226 and Th-232, being in equilibrium with the rest of the members of the uranium and thorium series, A_K – specific activity K-40 (Bq/kg).

The results of measurements of the specific activity of soil samples are presented in Table 5. According to the results of observations, it was found that the results of the specific effective activity of natural radionuclides in the samples of solid materials do not exceed the standard values. Moreover, during the execution of the work, 2 samples of underground water were taken at the considered license

areas. The samples were collected through a sampling valve from the well.

The volume of a groundwater sample for measuring the specific activity and spectrometric determination of the radionuclide composition is 3 liters. The samples of natural water were taken in specially prepared containers for storage and transportation. Each container was provided with a label containing information about the point of sampling [GOST 31861-2012].

The results of studies of water samples are presented in Table 6. Drilling waste in the form of drill cuttings needs further disposal and processing. The experience of processing drill cuttings and adding it to soil concrete for further use as a building material in the fields located in the Yamal-Nenets Autonomous Okrug: Yuzhno-Kharampurskoye, Severo-Komsomolskoye, Kharampurskoye, Festivalnoye, and Severo-Kharampurskoye, is noteworthy.

In this regard, it became necessary to determine the content of natural radionuclides and the parameters of the specific effective activity for the possibility of further use of the samples under study. According to the results of the study, the content of natural radionuclides in the soil-concrete samples at the indicated deposits and the parameters of the specific effective activity at the well pads do not exceed the standard values.

Thus, the application of this utilization method is possible at the Teplovskoye and Kudrinskoye fields.

Table 5. Results of measurements of specific activity of soil samples

Name of the study	Name of production facilities, divisions	Quantity	Specific activity of ⁴⁰ K, Bq/kg	Specific activity of ²²⁶ Ra, Bq/kg	Specific activity ²³² Th, Bq/kg	Specific effective activity of natural radionuclides, Bq/kg	Norm ≤370 Bq / kg
Kudrinsky license area							
Spectrometric determination of radionuclide composition and measurement of specific activity of soil samples at well pads	Workshop for oil and gas production-5, cluster of wells № 56	KT-1	315	25.7	8.8	65.5	≤370
		KT-2	384	10.8	11.4	60.1	
		KT-3	332	19.7	8.3	60.4	
		KT-4	423	28.7	9.9	79.7	
		KT-5	335	21.3	8.6	62.6	
Teplovsky license area							
Spectrometric determination of radionuclide composition and measurement of specific activity of soil samples at well pads	Workshop for oil and gas production-5, cluster of wells № 2	KT-1	380	17.3	7.2	61	≤370
		KT-2	394	13.2	20.4	75.2	
		KT-3	379	18.7	8.9	64.3	
		KT-4	312	16	8.8	55.5	
		KT-5	359	20.8	10.3	66.5	

Table 6. Results of measurements of the specific total α - and β - activity of formation water at the Teplovsky and Kudrinsky license areas

Name of the study	Name of production facilities, divisions	Quantity	Specific total α -activity (α -radioactivity), Bq/dm ³	Specific total β -activity (β -radioactivity), Bq/dm ³
Kudrinsky license area				
Spectrometric determination of radionuclide composition and measurement of specific activity of soil samples at well pads	Workshop for oil and gas production-5, cluster of wells № 56	1	0.69	0.87
Teplovsky license area				
Spectrometric determination of radionuclide composition and measurement of specific activity of soil samples at well pads	Workshop for oil and gas production-5, cluster of wells № 2	1	1.01	1.02

CONCLUSIONS

Nowadays, the methods owing to which it is possible not only to utilize, but also to obtain auxiliary products, are in great demand.

According to the results of the study of soil concrete with the addition of drill cuttings at the cluster pads of the South Kharampursky Severo-Komsomolsky, Kharampursky, Festivalny, Severo-Kharampursky fields, the content of the specific effective activity of natural radionuclides is in the range from 53 to 110 Bq/kg. In general, all the studied samples belong to the first class of building materials, and the research results do not exceed the standard values of 370 Bq/kg to 1500 Bq/kg, depending on the further use of processing and disposal of drilling waste at the fields.

As part of the study, the assessment of radiation pollution of the components of the natural environment (soil and formation water) at the Teplovsky and Kudrinsky license areas was carried out.

According to the results of observations, it can be concluded that modern production activities on the territory of the considered deposits of the Khanty-Mansiysk Autonomous Okrug-Yugra do not have a significant effect on the radiation background. No signs of general pollution and deterioration of the soil condition were found. The spectrometric determination of the radionuclide composition and the measurement of the specific activity of soil samples are at a comparable level.

The content of alpha and beta activity in formation waters is not regulated. In the analyzed samples, the values of alpha activity in the range from 0.034 to 1.03 and beta activity in the range from <0.100 to 1.02 were obtained.

Taking into account the analysis of the results of the state of the environment, it is recommended to continue the study of the radiation situation

on the territory of the license areas in the current volume; additional measures to improve the efficiency of the radiation and environmental monitoring system are not required.

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